

CONCRETE INFORMATION



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QUALITY CONCRETE
ARCHITECTURAL CONCRETE
TERRAZZO
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PRECAST JOIST
CONCRETE FLOORS

PORTLAND CEMENT ASSOCIATION

A National Organization to Improve and Extend the Uses of Concrete

33 West Grand Avenue

Chicago, Illinois

QUALITY CONCRETE GUIDE—With Tables of Quantities of Materials

Hardening of concrete mixtures is brought about by chemical reactions between the cement and water, the aggregates (sand, gravel, stone, etc.) being inactive ingredients used as fillers.

Use Proper Amount of Water—In proportioning concrete, the most important factor affecting strength, watertightness, durability and other qualities is the amount of mixing water used with each sack of cement. The less mixing water used, provided the concrete can be placed properly, the stronger, more watertight and more durable will be the concrete.

The proper amount of mixing water to use on a given job will usually depend on conditions of exposure. Experience and tests make it possible to make definite recommendations as in Table I for concrete made as recommended herein. At 28 days, such concretes should have compressive strengths of about 5,000, 4,000 and 3,000 lb. per sq. in. for 5, 6 and $7\frac{1}{2}$ gal. of mixing water, respectively.

Allow for Moisture in Sand—Sand as used on the job nearly always contains considerable moisture which is free to combine with cement. This moisture must be considered as part of the mixing water. On jobs where sand is shipped from a screening and washing plant, the average moisture is around 4 or 5 per cent by weight. (1 gal. water = 8.33 lb.) For accurate control, tests should be made to determine exact amount of moisture. This should be subtracted from the total mixing water to determine correct amount to add at the mixer. Tests may be made by surface-drying samples of the sand, weighing before and after drying. There is generally so little moisture in coarse aggregate it can be neglected.

Mixes and Quantities of Materials by Weight—On large jobs the aggregates are measured by weight. Even on small jobs, contractors are finding the weight measurement gives better control, more uniform results and better economy so that the equipment quickly pays for itself. A platform scale with runways on two sides to facilitate running wheelbarrows or carts onto the platform is used.

Table II gives approximate proportions and quantities of materials by weight for the three classes of concrete suggested in Table I. The consistency that can be used will depend on the placing conditions. Proportions and quantities are therefore shown for stiff, medium and wet concrete.

In this table moisture in the sand is assumed to be 5 per cent by weight. The weight of sand has been corrected for this moisture. The corrected amount of water to add at the mixer after deducting moisture is also shown. This is the proper amount of water, which should be measured as accurately as possible.

Use a Workable Mixture—Should the proportions of sand and coarse aggregate selected give a mixture which is not workable, they should be adjusted to produce a mixture suitable for the job but *without exceeding the recommended amount of mixing water*. The concrete should be a plastic mass which holds together during handling and placing. Very stiff mixes can be used when concrete is placed by vibration. Mixtures which permit water to rise to the surface or permit mortar to separate from coarse material should be avoided whether placing is by hand or by vibration.

Mixes and Quantities of Materials by Volume—Moisture causes a very appreciable swelling of sand, up to 30 per cent or more. The amount of swelling is affected by the grading of the sand and the amount of moisture. Since these will vary from job to job, tables of proportions and quantities by volume can not be accurate. Table III gives volume proportions and quantities for a certain set of conditions as indicated. The quantities shown will not, of course, be accurate if the moisture or weight per cubic foot of the aggregates to be used is greatly different from the assumed values.

More accurate volumetric estimates can be made by using Table II as follows: First, weigh a cubic foot of each aggregate to be used, measured damp and loose. From Table II get the total batch weight of each aggregate. Divide these totals by the weight per cubic foot of the corresponding aggregate, as determined. This gives the cubic feet of sand and coarse aggregate per sack of cement.

Measure Material Accurately—Each ingredient should be accurately measured. Cement is furnished in sacks weighing 94 lb., considered as 1 cu. ft. Fractional bags should not be used unless they are weighed for each batch. As stated previously, weight measurement of aggregates gives best results.

When scales are not available a cubic foot box may be used. Usually the proper amount of sand is measured by the box into one wheelbarrow and the proper amount of coarse aggregate into another wheelbarrow, observing or marking the level to which each is filled. Wheelbarrows are then filled to these levels for each batch, dispensing with the box.

Water may be measured by buckets or by the tank on the mixer if it has an accurate measuring device. The capacity of a bucket may be determined by filling it with water from a quart measure, placing a mark on the inside of the bucket to indicate the proper amount. (1 qt. = $\frac{1}{4}$ gal.) If a measuring device on the mixer is used, find out how much water is measured at each setting on the dial. This is done by discharging the water measured at each dial-setting into buckets of known capacity.

Use Good Materials—Sand, gravel, crushed stone or other aggregates for concrete work must be clean and free from clay, loam and dirt. Usually washed and screened materials assure best results. Mixing water should be clean enough to drink.

Coarse materials give more economical results than finer materials. This is because each particle must be thoroughly coated by cement paste and less paste is required for a given volume of coarse particles than for the same volume of small particles. Best results are secured with graded aggregates, that is, aggregates containing particles ranging from fine to coarse, with coarse predominating. Sufficient fine particles are necessary, however, to give workability and smooth surfaces. Generally, sand should contain from 10 to 20 per cent of particles passing a 50-mesh sieve.

Materials should be kept in separate piles. Cement should be kept in a dry place as in a building or on a platform raised off the ground and covered with tarpaulins.

Keep New Concrete Moist—The chemical reactions between cement and water require time. Under favorable conditions of moisture and temperature they continue indefinitely. Thus the strength, hardness, watertightness, durability and other qualities continue to improve under the right conditions.

For continued improvement concrete must be kept moist. When the water used in mixing is lost by evaporation, the chemical reactions cease. Concrete should be protected from early drying by leaving forms in place, covering exposed surfaces with wet sand, burlap or other materials and by sprinkling. This wet "curing" should be started as soon as possible without marring the surfaces and should be continued as long as possible—at least a week in most cases when standard portland cement is used and 2 or 3 days when standard high early strength portland cement or concrete is used.

TABLE I—RECOMMENDED AMOUNTS OF MIXING WATER FOR CONCRETE TO MEET DIFFERENT DEGREES OF EXPOSURE

Gallons Per Sack of Cement				
Exposure	Class of structure	Reinforced piles, thin walls, light structural members, exterior columns and beams in buildings.	Reinforced reservoirs, water tanks, pressure pipes, sewers, canal linings, dams of thin sections and all other watertight structures.	Heavy walls, piers, foundations, dams of heavy sections.
Extreme: (1) In severe climates like in northern U.S., exposure to alternate wetting and drying, freezing and thawing, as at the water line in hydraulic structures. (2) Exposure to sea and strong sulphate waters* in both severe and moderate climates.		5	5	6
Severe: (3) In severe climates like in northern U.S. exposure to rain and snow, and freezing and thawing, but not continuously in contact with water. (4) In moderate climates like southern U.S., exposure to alternate wetting and drying, as at water line in hydraulic structures.		6	6	6
Moderate: (5) In climates like southern U.S., exposure to ordinary weather, but not continuously in contact with water. (6) Concrete completely submerged, but protected from freezing.		6	6	$7\frac{1}{2}$
Protected: (7) Ordinary inclosed structural members; concrete below the ground and not subject to action of corrosive ground water or freezing and thawing.		$7\frac{1}{2}$	6	$7\frac{1}{2}$

*Waters containing sodium and magnesium sulphates, often referred to as alkali waters, also sewage and similar liquids.

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TABLE II—WEIGHT OF MATERIALS REQUIRED FOR CONCRETE

Consistency	Materials Per Sack of Cement						Yield—cu. ft. of concrete per sack cement	Cement sacks	Materials Required Per Cubic Yard of Concrete				
	With Gravel			With Crushed Stone					With Gravel		With Stone		
	Sand lb.	Gravel lb.	Water* gal.	Sand lb.	Stone lb.	Water* gal.			Sand lb.	Gravel lb.	Sand lb.	Stone lb.	
WITH 1-INCH AGGREGATE													
5 Gallons Total Water Per Sack of Cement													
Stiff.....	189	307	3.9	225	273	3.7	4.09	6.6	1253	2325	1480	1805	
Medium.....	167	271	4.0	199	241	3.8	3.75	7.2	1230	1950	1430	1740	
Wet.....	149	241	4.2	177	215	3.9	3.46	7.8	1160	1875	1380	1670	
6 Gallons Total Water Per Sack of Cement													
Stiff.....	232	360	4.6	297	318	4.2	4.91	5.5	1390	1980	1630	1750	
Medium.....	224	320	4.7	263	283	4.4	4.50	6.0	1350	1920	1580	1700	
Wet.....	201	286	4.8	236	253	4.6	4.15	6.5	1310	1860	1530	1640	
7½ Gallons Total Water Per Sack of Cement													
Stiff.....	350	441	5.4	406	386	5.1	6.13	4.4	1540	1940	1790	1700	
Medium.....	312	392	5.6	362	344	5.3	5.62	4.8	1500	1880	1740	1650	
Wet.....	278	351	5.8	323	307	5.5	5.19	5.2	1450	1820	1680	1600	
WITH 2-INCH AGGREGATE													
5 Gallons Total Water Per Sack of Cement													
Stiff.....	199	366	3.8	234	333	3.7	4.50	6.0	1190	2200	1400	2000	
Medium.....	175	321	4.0	205	292	3.8	4.09	6.6	1160	2115	1350	1920	
Wet.....	155	284	4.2	181	258	3.9	3.75	7.2	1120	2040	1300	1860	
6 Gallons Total Water Per Sack of Cement													
Stiff.....	266	428	4.5	307	398	4.2	5.40	5.0	1330	2140	1540	1940	
Medium.....	234	378	4.7	272	342	4.4	4.91	5.5	1290	2080	1500	1880	
Wet.....	208	336	4.8	241	304	4.6	4.50	6.0	1250	2020	1450	1820	
7½ Gallons Total Water Per Sack of Cement													
Stiff.....	369	525	5.2	424	473	5.0	6.75	4.0	1470	2100	1690	1890	
Medium.....	325	464	5.6	373	418	5.2	6.13	4.4	1430	2040	1650	1840	
Wet.....	290	413	5.8	332	372	5.5	5.62	4.8	1390	1980	1600	1780	

*Amount of water to add allowing for moisture in sand.

This table is based on aggregates of 2.65 specific gravity and sand containing 5 per cent moisture by weight. No allowance has been made for waste.

Avoid Low Temperatures—Favorable temperature is the second requirement for continued improvement. The reactions between cement and water are more rapid at high than at low temperatures. Near freezing, the reactions almost cease. Concrete moistured at 70 deg. F. for a week may have twice the strength of similar concrete cured at 50 deg. F. In mildly cold weather, the water may be heated to raise the temperature of the concrete to 70 deg. F. In freezing weather, the water and aggregates should be heated so that the temperature of the mixed concrete is between 70 and 100 deg. F. It should then be kept above 70 deg. F. for 3 days or above 50 deg. F. for 5 days for standard portland cement concrete, and above 70 deg. F. for 2 days or 50 deg. F. for 3 days when standard high early strength portland cement or concrete is used. Salt or other chemicals should not be used to lower the freezing point of concrete.

General Suggestions—Mix concrete thoroughly. Do not over-

load mixers or operate them at speeds higher than recommended by the manufacturer. Continue mixing for at least a minute after all materials are in the mixer. Longer mixing gives more uniform results.

Handle and place concrete carefully to prevent the materials from separating. It should not be dropped into place more than 5 or 6 ft. Place it in the forms where it is to stay, and in horizontal layers, usually not over 1 to 2 ft. thick. Do not allow the concrete to flow over long distances in the forms, as this causes the materials to separate. Spade each layer to settle the concrete, release air, remove stone pockets and provide smooth surfaces along the forms.

Do not trowel or float concrete excessively while it is soft. Such working of the surface brings water and fine materials to the top which, upon hardening, has a tendency to check and crack. Best results are secured by allowing the concrete to stand until it is quite stiff before finishing.

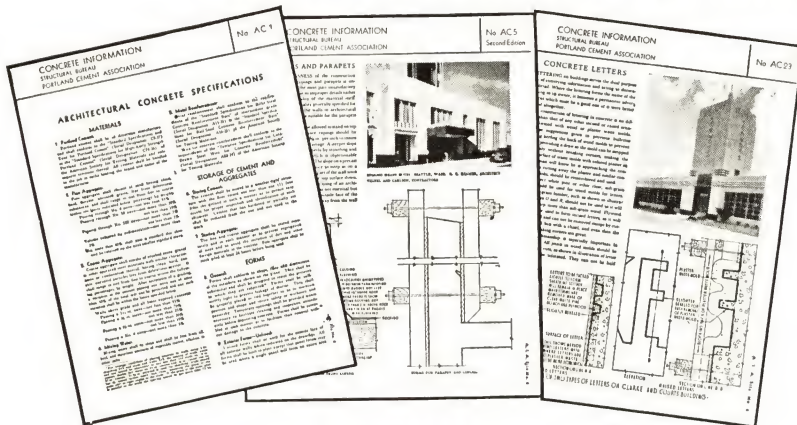
TABLE III—VOLUME OF MATERIALS REQUIRED FOR CONCRETE—AGGREGATES MEASURED BY DAMP LOOSE VOLUME

Consistency	Mix with gravel	Water* added with gravel— gal. per sack	Mix with crushed stone	Water* added with crushed stone—gal. per sack	Yield cu. ft. of concrete per sack cement	Materials Required for One Cubic Yard of Concrete								
						Cement sacks	With Gravel				With Crushed Stone			
							Sand		Gravel		Sand		Stone	
							cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
WITH 1-INCH AGGREGATE														
Total Mixing Water 5 Gallons Per Sack of Cement														
Stiff	1 2.1-3.1	3.9	1-2.5-2.8	3.7	4.09	6.6	14.1	.52	20.4	.76	16.6	.62	18.2	.67
Medium	1 1.9-2.7	4.0	1-2.2-2.4	3.8	3.75	7.2	13.6	.50	19.7	.73	16.0	.59	17.6	.65
Wet	1 1.7-2.4	4.2	1-2.0-2.2	3.9	3.46	7.8	13.1	.49	19.0	.70	15.5	.57	16.9	.63
Total Mixing Water 6 Gallons Per Sack of Cement														
Stiff	1 2.8-3.6	4.6	1-3.3-3.2	4.2	4.91	5.5	15.6	.58	20.0	.74	18.3	.68	17.7	.66
Medium	1 2.5-3.2	4.7	1-3.0-2.9	4.4	4.50	6.0	15.1	.56	19.4	.72	17.7	.66	17.2	.64
Wet	1 2.3-2.9	4.8	1-2.6-2.6	4.6	4.15	6.5	14.6	.54	18.8	.70	17.2	.64	16.6	.62
Total Mixing Water 7½ Gallons Per Sack of Cement														
Stiff	1 3.9-4.5	5.4	1-4.6-3.9	5.1	6.13	4.4	17.2	.64	19.6	.73	20.1	.74	17.2	.64
Medium	1 3.5-4.0	5.6	1-4.1-3.5	5.3	5.62	4.8	16.8	.62	19.0	.70	19.5	.72	16.7	.62
Wet	1 3.1-3.5	5.8	1-3.6-3.1	5.5	5.19	5.2	16.3	.60	18.3	.68	18.9	.70	16.2	.60
WITH 2-INCH AGGREGATE														
Total Mixing Water 5 Gallons Per Sack of Cement														
Stiff	1 2.2-3.7	3.8	1-2.6-3.4	3.7	4.50	6.0	13.3	.49	22.2	.82	15.7	.58	20.2	.75
Medium	1 2.0-3.2	4.0	1-2.3-3.0	3.8	4.09	6.6	13.0	.48	21.4	.79	15.2	.56	19.4	.72
Wet	1 1.7-2.9	4.2	1-2.0-2.6	3.9	3.75	7.2	12.5	.46	20.6	.76	14.6	.54	18.8	.70
Total Mixing Water 6 Gallons Per Sack of Cement														
Stiff	1 3.0-4.3	4.5	1-3.4-4.0	4.2	5.40	5.0	14.9	.55	21.6	.80	17.2	.64	19.6	.73
Medium	1-2.6-3.8	4.7	1-3.0-3.5	4.4	4.91	5.5	14.4	.53	21.0	.78	16.8	.62	19.0	.70
Wet	1 2.3-3.4	4.8	1-2.7-3.1	4.6	4.50	6.0	13.9	.52	20.4	.76	16.3	.60	18.4	.68
Total Mixing Water 7½ Gallons Per Sack of Cement														
Stiff	1-4.1-5.3	5.2	1-4.7-4.8	5.0	6.75	4.0	16.5	.61	21.2	.79	19.0	.70	19.1	.71
Medium	1-3.6-4.6	5.6	1-4.2-4.2	5.2	6.13	4.4	16.0	.59	20.6	.76	18.4	.68	18.6	.69
Wet	1-3.2-4.2	5.8	1-3.7-3.8	5.5	5.62	4.8	15.6	.58	20.0	.74	17.9	.66	18.0	.67

*Corrected for free moisture carried by sand.

This table is based on the following assumptions: Absorption of aggregates 1 per cent by weight; free moisture in sand 5 per cent by weight; coarse aggregate surface dry; weight of sand 89 lb. per cu. ft. measured damp, loose; weight of coarse aggregate 99 lb. per cu. ft. measured loose.

ARCHITECTURAL CONCRETE SPECIFICATIONS



MATERIALS

(1) **Portland Cement**—Portland cement shall be of American manufacture conforming to the "Standard Specifications and Tests for Portland Cement" (Serial Designation: C9-38) or the "Standard Specifications for High-Early Strength Portland Cement" (Serial Designation: C74-38) of the American Society for Testing Materials and subsequent revisions thereof. All cement shall be handled to the job in sacks bearing the brand and name of the manufacturer.

(2) **Fine Aggregate**—Fine aggregate shall consist of sand having clean, hard, durable, uncoated grains, free from deleterious substances, and shall range in size from fine to coarse within the following percentages by weight:

Passing No. 4 sieve.....	95 to 100 per cent
Passing No. 16 sieve.....	45 to 70 per cent
Passing No. 50 sieve.....	15 to 30 per cent
Passing No. 100 sieve.....	3 to 8 per cent

Volume removed by sedimentation—not more than 3 per cent. Not more than 40 per cent shall pass a standard size sieve and be retained on the next smaller standard sieve.

(3) **Coarse Aggregate**—Coarse aggregate shall consist of crushed stone, gravel or other approved inert materials with similar characteristics or combination thereof, having clean, hard, durable, uncoated particles free from deleterious matter. After acceptance of a grading, a variation in the amount passing any sieve size of more than 10 per cent of the total will not be permitted and the grading shall be within the following percentages, by weight:

Passing a 1½-in. sieve.....	95 to 100 per cent
Passing a ¾-in. sieve.....	35 to 70 per cent
Passing a ⅜-in. sieve.....	10 to 30 per cent
Passing a No. 4 sieve.....	0 to 5 per cent

(4) **Deleterious Substances**—Deleterious substances shall not be present in the fine and coarse aggregates in excess of the amounts shown in the following table:

Aggregate	Deleterious Substance—Percentage by Weight			
	Clay Lumps	Coal and Lignite	Material Finer than No. 200 Sieve	Soft Fragments
Fine.....	1	½	4	...
Coarse.....	¼	½	1	3

(5) **Soundness**—The fine and coarse aggregates when subjected to five alternations of the sodium sulfate soundness test (A.S.T.M. Designation: C89-35T) shall not show an average weighted loss of more than 10 per cent for the fine aggregate and 13 per cent for the coarse aggregate, unless evidence satisfactory to the Architect is furnished that concrete of comparable proportions in which similar materials from the same sources were used, has been exposed to natural weathering for a period of at least 5 years without appreciable disintegration.

(6) **Mixing Water**—Mixing water shall be clean and shall be free from oil, acid, and injurious amounts of vegetable matter, alkalies, or other salts.

(7) **Metal Reinforcement**—Metal reinforcement shall conform to the requirements of the "Standard Specifications for Billet-Steel Concrete Reinforcement Bars" of Intermediate grade (Serial Designation: A15-35) or the "Standard Specifications for Rail-Steel Concrete Reinforcement Bars" (Serial Designation: A16-35) of the American Society for Testing Materials.

Wire for concrete reinforcement shall conform to the requirements of the "Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement" (Serial Designation: A82-34) of the American Society for Testing Materials.

STORAGE OF CEMENT AND AGGREGATES

(8) **Storing Cement**—Cement shall be stored in a weather-tight structure with the floor raised not less than 1 ft. from the ground in such manner as to permit easy access for proper inspection and identification of each shipment. Cement that has hardened or partially set shall be removed from the site and not used in the work.

(9) **Storing Aggregate**—Fine and coarse aggregates shall be stored separately and in such manner as to prevent segregation of sizes and to avoid the inclusion of dirt and other foreign materials in the concrete. Fine aggregate shall be stock piled at least 24 hours before being used.

FORMS

(10) **General**—Forms shall conform to shape, lines and dimensions of the members as shown on the plans. They shall be properly braced or tied together to maintain position and shape and insure safety to workmen and passersby. Forms shall be made sufficiently tight to prevent leakage of mortar. All exterior forms shall be detailed and drawings submitted to the Architect for approval before forms are fabricated or erected.

Studs and walers shall be not less than 2x4 in. S1S1E or S4S and shall be No. 2 or better Southern Pine, Douglas Fir or equal. All walers shall be doubled and the joints in the top and bottom pieces of each waler shall be staggered at least the spacing of the form ties. Vertical kick strips shall be used at the intersection of the walers at all external corners.

Forms shall be substantial and designed to resist the pressure to which they are subjected, but under no conditions shall studs be spaced more than 16-in. centers when used with 1-in. sheathing or ¾-in. structural grade plywood, and when used with plywood having the grain of the outer plies parallel to the studs the stud spacing shall not be greater than 12-in. centers. Walers shall be spaced not more than 24-in. centers and ties shall be spaced not more than 27-in. centers when used with double 2x4-in. walers. Ties shall have a minimum working strength of 3,000 lb. when fully assembled.

If a lift of forms is 12 ft. or more high and at all spandrel beams regardless of the height of the forms, double 2x6-in. vertical walers spaced not more than 10-ft. centers and extending the full height of the forms shall be bolted to every other set of horizontal walers to maintain the forms in straight, true alignment.

Temporary openings shall be provided where necessary to facilitate cleaning and inspection immediately before depositing concrete. Forms shall be so assembled that their removal will not damage the concrete.

(11) **Exterior Forms—Unlined**—Unlined forms shall be used for the outside face of all exterior walls where indicated on the drawings. All forms shall be built in place except that panel forms may be used where a single panel will form an entire area from one reveal to another. The use of panel forms will not be permitted where the joints between adjacent panels must be made on flat surfaces or in any other conspicuous locations.

The contact surface of all unlined forms shall be constructed of No. 1 common dressed and matched Longleaf Southern Yel-

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low Pine or Douglas Fir boards.† This material shall be delivered to the site immediately on signing the contract and shall be sorted and graded on the job. The best 25 to 30 per cent of each load shall be selected for the outside face forms. The selected sheathing shall be stacked clear of the ground in layers separated by ¼-in. laths to facilitate air drying.

Note: Use the following paragraph in place of the preceding one and omit the fourth paragraph of this section if plywood is used for sheathing.

The contact surface of all unlined forms shall be constructed of ⅝ or ¾-in. 5-ply Douglas Fir plywood made with a waterproof glue and especially manufactured for concrete formwork. Full-sized sheets of plywood must be used except where smaller pieces will cover an entire area. All horizontal and vertical joints shall be backed solidly to prevent leakage and the edges of abutting sheets shall be nailed to the same stud or blocking with 6d box nails not farther apart than 8 in. Wherever panel forms are permitted by the Architect the joints shall be so constructed as to comply with the above requirements.

Vertical boarding shall have all vertical joints truly plumb and all horizontal boarding shall have all horizontal joints exactly level and without changes in level in any horizontal line. Portions of full-width boards will not be permitted adjacent to construction joints. The vertical joints in horizontal boarding shall not be over one board wide and shall be staggered at least 2 ft. and shall not be made except at studs or girts. Each board shall be driven up snug and nailed to every stud or girt with 8d box nails. All 6-in. sheathing shall be double nailed, and 8 and 10-in. boards shall be nailed at both edges and at center. The three top boards adjacent to horizontal construction joints shall not be erected until after the wetting operation specified in Sec. 15 has been completed, and to fill the remaining space each board shall be ripped to approximately one-third of the height between the top full-width board and construction joint. Form boards shall not be re-used a second time in contact with exposed surfaces unless approved by the Architect.

When the outside form is erected and pointed as may be required with a mixture of equal parts of beef tallow and portland cement and reinforcing is in place and before the inside form is erected the Architect shall be notified and the inside form shall not be placed until work already done is approved.

(12) Exterior Forms—Lined—The backing for form lining shall be constructed of a good grade of form lumber that is solid, straight, and free from defects that might impair its strength but need not be of the quality used for contact forms. Square-edged lumber may be used for form boarding in place of shiplap or T&G. The boarding for lined forms may be horizontal or vertical, depending upon convenience. Form sheathing shall be securely nailed to studs and so spaced as to prevent any bulging of the lining.

Non-warping fibre board not less than ¾ in. in thickness, or ¼-in. plywood, shall be securely nailed to the form sheathing. All lining material shall be used in as wide pieces as possible. Areas less than 4 ft. in width shall be lined with a single width of fibre board.

Joints in lining and backing shall not occur at the same place and abutting edges of adjacent sheets shall be nailed to the same board. The lining material shall be nailed to the backing beginning at the center of the board and working toward the edges to prevent buckling. Three-penny blue shingle nails or similar nails with thin flat heads shall be used to attach lining material to sheathing. The nails shall not be farther apart than 8 in. along the edges and there shall be at least one nail for every square foot of surface. The edges of the lining shall be butted tight together, or joints between the sheets shall be filled with a mixture of equal parts of beef tallow and portland cement. Lining material may be re-used if it is in satisfactory condition and is approved by the Architect.

Presdwood shall be thoroughly wet with water at least 12 hours before being used. The water shall be applied to the screen side of the board and the board shall be stacked screen side to screen side.

(13) Ornamental Detail—Ornamental concrete work shall be

† If an impression in the concrete of knots and other flaws in the wood is desired No. 2 boards may be used. For rough-textured surfaces re-sawed square-edged No. 1 or No. 2 boards, or boards surfaced one side and two edges may be used with the rough side of the lumber used as the contact surface. The width of form boards varies from 4 to 8 in., depending on the scale of the building and the effect desired. Boards of 1-in. nominal thickness are generally used. ⅝-in. 5-ply Douglas Fir plywood may be used in place of boards for sheathing where a surface practically free from joint lines is desired. Proper substitution should be made in the specifications to require the type of sheathing material to be used that will give the surface finish desired.

placed integrally with the body of the concrete in wood molds or plaster waste molds. Moldings, column fluting and simple ornament shall be formed with wood, using No. 2 or better Idaho White Pine or equal. No material thicker than 2 in. shall be used without approval of the Architect and members making up wood molds shall be kerfed on the back wherever such members may become wedged between projections in the ornament. Molds shall be so constructed that joints will not be opened by slight movement and swelling of the wood. Joints in the molds shall be broken and made as inconspicuous as possible by pointing where necessary with water putty, patching plaster or similar material.

Intricate detail that cannot be formed with wood molds shall be cast in waste molds made from models approved by the Architect and shall be of such thickness and be so reinforced with fibre and a framework of wood that they may be readily handled without breakage. Waste molds shall be sized with two coats of thin shellac. Wherever waste molds require pointing or patching, the work shall be done with patching plaster and shall be shellacked after drying but damaged molds shall not be patched without approval of the Architect.

The plaster waste molds shall be carefully set in the forms and securely held in the exact position to reproduce the design shown on the drawings. The framing of the wood form above the mold shall be sufficiently strong to remove all load from the molds. Where wood forms adjoin waste molds, the wood shall be neatly fitted to the profile of the molds and all joints shall be carefully pointed to eliminate jointing.

(14) Form Ties—Form ties approved by the Architect shall be used. They shall have a minimum working strength when fully assembled of at least 3,000 lb. Ties shall be adjustable in length and of such type as to leave no metal closer than 1½ in. of the surface and they shall not be fitted with any lugs, cones, washers or other device to act as a spreader within the form or for any other purpose which will leave a hole larger than ⅝ in. in diameter or a depression back of the exposed surface of the concrete. Wire ties will not be permitted.

Ties that are to be pulled from the wall shall be coated with cup grease or other approved material to facilitate removal.

Tie rod clamps that are to be entirely removed from the wall shall be loosened 24 hours after the concrete is placed. All but a sufficient number of ties to hold the forms in place may be removed at that time, but the forms shall be held in position not less than 4 days, except that 2 days shall be considered sufficient if high early strength portland cement or concrete is used, but in no case shall ties or forms be removed until the concrete has hardened sufficiently to permit removal without damaging the concrete. Care shall be exercised to avoid spalling the concrete on the exposed surfaces. Ties of uniform diameter that are wholly withdrawn from the wall shall be pulled toward the inside face. Cutting ties back from the face of the wall will not be permitted. Tie rod holes shall be plugged as specified in Sec. 36.

(15) Wetting and Oiling Forms—The inside surface of wood forms shall be soaked continuously with clean water for 12 hours before any concrete is placed. In case forms have been erected for some time and have become dry so that joints have opened, then the forms shall be thoroughly soaked at least twice each day for at least 3 days prior to placing concrete. Plywood and Presdwood forms shall be treated with an approved form oil or lacquer. If oil is used all excess oil shall be wiped off with rags to leave the surface of the forms just oily to the touch. Plaster waste molds shall be greased with soft cup grease or cup grease thinned to a point where it can be applied with a brush by addition of a mixture of crystallized stearic acid and kerosene.

Concrete shall not be placed in any form until inspected by the Architect and permission is given to start placing.

(16) Removing Forms—All wall forms shall be removed when the concrete has thoroughly hardened, but in no case in less than 4 days except when high early strength cement or concrete is used, in which case forms may be removed after 2 days. Waste molds shall be left in place until thoroughly dry and until all placing of concrete has been completed and in no case less than 14 days and shall then be carefully stripped off to prevent damage to the concrete.

REINFORCEMENT

(17) Cleaning—Metal reinforcement before being placed shall be thoroughly cleaned of mill and rust scale and of coatings that will destroy or reduce the bond. Reinforcement appre-

ciably reduced in section shall be rejected. Where there is delay in depositing concrete, reinforcement shall be reinspected and when necessary cleaned.

(18) Bending and Straightening—Reinforcement shall be carefully formed to the dimensions indicated on the plans. Cold bends shall be made around a pin having a diameter of six or more times the least dimensions of the reinforcement bars.

Metal reinforcement shall not be bent or straightened in a manner that will injure the material. Bars with kinks or bends not shown on the plans shall not be used. Heating of reinforcement will be permitted only when the entire operation is approved by the Architect.

(19) Placing—Metal reinforcement shall be accurately positioned and secured against displacement by using annealed wire of not less than No. 16 gage or suitable clips at intersections and shall be supported in a manner that will keep all metal away from the exposed surface of the wall. Nails shall not be driven into the outside forms to support reinforcement nor shall any other device for this purpose come in contact with the outside form, except that wood strips shall be inserted between the reinforcement and the outside form at intervals to maintain the required clear distance. The strips shall be pulled up and removed from the wall as the level of the concrete rises. The minimum clear distance between any bar and the weather side of all exterior walls shall not be less than 2 in. At all wall surfaces not exposed to the weather a minimum of 1 in. of concrete cover over all steel shall be provided.

(20) Splicing—Wherever it is necessary to splice reinforcement otherwise than as shown on the plans, the character of the splice shall be decided by the Architect on the basis of allowable bond stress and the stress in the reinforcement at the splice. Splicing shall not be made on points of maximum stress nor shall adjacent bars be spliced at the same point.

All bars shall be lapped at least 40 diameters at all corners and at abrupt changes in directions of walls.

PROPORTIONING

(21) General—Fine and coarse aggregates shall be proportioned by direct weight upon suitable weighing devices approved by the Architect. Portland cement in standard unopened cloth or paper sacks as packed by the manufacturer may be considered as weighing 94 lb. per sack.

(22) Measuring Ingredients—All measurements of fine and coarse aggregates shall be made separately by weight. Proportioning aggregates for fractional sacks of cement will not be permitted unless the cement is weighed for each batch. Weighing equipment shall be arranged to permit making compensation for changes in the weight of moisture contained in the aggregates. Weighing equipment shall meet the approval of the Architect and shall be accurate within 1 per cent of the net load being weighed.

A satisfactory auxiliary device shall be used in connection with the scale beam to indicate or register at least the last 100 lb. of each of the aggregates required for the batch. The weighing hopper shall be equipped with a means of adjusting the volume of the compartment in which the aggregates are weighed.

Water shall be measured by an approved device capable of accurate measurement to 1 pt., plus or minus, of the total amount of water required per batch.

(23) Water-Cement Ratio—The proportioning of materials shall be based on the requirements for a plastic and workable mix with the use of not less than $5\frac{1}{2}$ sacks of cement per cu.yd. and not more than $6\frac{1}{2}$ gal.* of water per sack of cement including the surface water carried by the aggregate, expressed in terms of the quantity of cement. The water in the aggregate must be included in the quantity specified and subtracted from the amount added to the mixture. It shall be measured by methods satisfactory to the Architect which will give results within 1 lb. for each 100 lb. of aggregate. Moisture determinations shall be made on representative samples at least once each day and at such other times as the appearance of the aggregate or the mixed concrete indicates a change in moisture content.

(24) Proportioning and Consistency—The proportions of aggregate to cement shall produce concrete that can be thoroughly compacted. The slump shall not exceed 4 in. when vibration equipment is used and in no case shall the slump exceed 6 in.

The combined aggregate shall be of such composition of sizes that when separated by the No. 4 standard sieve the weight retained on the sieve shall be not less than one-half nor more

than two-thirds of the total based on dry materials, except where adjustment is necessary in the opinion of the Architect for casting in special details.**

(25) Trial Batches—Full size trial batches shall be made in the mixer using the aggregates selected for the job to establish the correct proportions of the mix to give proper workability without exceeding the water-cement ratio and slump specified. If the desired workability is not obtained with the first combination of aggregates, then the proportions of fine and coarse aggregate shall be adjusted within the limits specified until the mix meets with the approval of the Architect.

(26) Mixing—Concrete shall be mixed in a batch mixer for not less than 1 minute after all the materials are in the mixer drum and until there is a uniform distribution of the materials and the mass is uniform in color and is homogeneous. The mixer shall rotate at a peripheral speed of about 200 ft. per minute and shall not be loaded above its rated capacity.

(27) Central or Transit-Mixed Concrete—Concrete from a central plant or mixed in transit-mixer trucks may be used if it complies with these specifications. The Architect shall have free access at all times to the batching and mixing plant for sampling of all materials and inspection of work performed for this project. Concrete shall be delivered in watertight containers which will not permit segregation of the materials. When delivered, the concrete shall be uniform throughout the mass.

DEPOSITING CONCRETE

(28) Cleaning Equipment—Before beginning a run of concrete, hardened concrete and foreign materials shall be removed from the inner surfaces of the mixing and conveying equipment. All conveyances, buggies, or barrows shall be thoroughly cleaned at frequent intervals during the placing of the concrete.

(29) Transporting—Concrete shall be handled from the mixer to the place of final deposit in carts, buggies or conveyors and shall not be spouted nor delivered by spout or trough from the hoists, nor dumped into carts with a free fall from the mixer of more than 3 ft. Every possible precaution shall be taken to prevent separation or loss of the ingredients while transporting the concrete. Delivery carts or buggies shall be kept on temporary runways built over the floor system and runway supports shall not bear upon reinforcing steel or fresh concrete.

(30) Time of Placing—Before starting work on any exposed concrete the Contractor shall construct complete and finish a section of basement wall or other unexposed wall where directed by the Architect as a demonstration panel, using the same materials and methods of construction as will be used for exposed surfaces.

Concrete shall not be placed until all reinforcement is securely and properly fastened in its correct position, nor until the forms have been inspected and approved by the Architect and form ties at construction joints have been retightened, nor until all bucks, sleeves, hangers, pipes, conduits, bolts, wires and any other fixtures required to be embedded therein have been placed and anchored by the Contractors, nor until the forms and reinforcement have been cleaned and the forms oiled or lacquered as specified in Sec. 15. Concrete shall not be placed at any time except under the direct supervision of the Architect nor outside of regular working hours unless the Architect is notified at least 4 hours in advance and Architect's superintendent or inspector is on the job.

(31) Placing—Special care must be exercised to prevent segregation of the concrete and to prevent splashing the forms or reinforcement with concrete and any such splashes or accumulations of hardened or partially hardened concrete on the forms or reinforcement above the general level of the concrete already in place must be removed before the work proceeds. Concrete shall be placed through "elephant trunks" (No. 20 gage galvanized iron chutes 4x12 in. in cross-section) equipped with suitable hopper heads. Chutes shall be of variable lengths so that the free fall shall not exceed 3 ft., and a sufficient number shall be placed in the forms to insure the concrete being kept level at all times. Sufficient illumination shall be provided in the interior of the forms so that the concrete at places of deposit is visible from the deck and runways. Plaster waste molds shall be protected by a canvas cover over the inside face of each mold which shall remain in place until the level of the

* In Southern climates where there is little or no freezing and thawing this may be increased by $\frac{1}{2}$ gal. per sack of cement and the minimum cement content per cubic yard may be reduced to $5\frac{1}{4}$ sacks.

** In practically all cases the regular mix can be used for casting details. Where detail is intricate it may be necessary to reduce the amount of coarse aggregate but it is rarely necessary to reduce the maximum size.

C O N C R E T E I N F O R M A T I O N

concrete in the wall form reaches the middle of the mold or a point at least 1 ft. above the bottom of the mold. The canvas shall be slowly lifted, allowing the concrete to enter the mold. Every precaution shall be taken to completely fill the mold.

Concrete shall be spaded to thoroughly embed all reinforcement and fixtures. Spading shall be supplemented by rapping the forms with rubber hammers or wooden mallets or by light pneumatic or electric hammers (chipping guns) applied to the studs and wales at the level of the concrete being placed. When forms are removed, surfaces shall be even and dense, free from aggregate pockets or honeycomb.

Note: If concrete is to be vibrated substitute the following section for the last paragraph of Sec. 31.

(31a) Placing with Vibration—Concrete shall be placed with the aid of mechanical vibrating equipment. Where vibration is used it shall be applied directly to the concrete unless otherwise approved by the Architect. The intensity of vibration shall be sufficient to cause flow or settlement of the concrete into place. Vibration shall be applied at the point of deposit and in the area of freshly placed concrete. It shall be of sufficient duration to accomplish thorough compaction and complete embedment of reinforcement and fixtures as approved by the Architect.* To secure even and dense surfaces, free from aggregate pockets or honeycomb, vibration shall be supplemented by hand spading in the corners and angles of forms and along form surfaces while the concrete is plastic under the vibratory action.

(32) Construction Joints and Stoppages—The placing of concrete shall be carried on continuously between construction joints shown on the drawings.** If for any reason it shall become necessary to stop the placing of concrete at places other than those indicated, such places shall have the approval of the Architect.

Immediately after concrete placement is completed, the reinforcement projecting above the concrete shall be thoroughly cleaned. The surface of the concrete shall be level whenever a run of concrete is stopped. To insure a level, straight joint on the exposed surface of the walls a strip of 1-in. sheathing shall be tacked to the forms at the outside surface of the wall. The concrete shall be carried about ½ in. above the underside of the strip. About 1 hour after the concrete is placed, the strip shall be removed and any irregularities in the joint line shall be leveled off with a wood float and all laitance shall be removed with a stiff wire brush, leaving the aggregate exposed. Wherever horizontal construction joints are made, ⅝-in. bolts shall be provided 3 to 4 in. below the joint at the same spacing as regular ties with which to tighten the forms against the hardened concrete.

Vertical stops shall be placed at interior corners only, unless otherwise shown on the drawings or approved by the Architect.

(33) Depositing Against Other Concrete—Before depositing new concrete on or against concrete that has hardened, the forms shall be retightened, the surface of the hardened concrete shall be roughened as required, thoroughly cleaned of foreign matter and laitance, and moistened with water. The new concrete placed in contact with hardened or partially hardened concrete shall contain an excess of mortar to insure bond. To insure sufficient mortar at the juncture of the hardened and the newly deposited concrete, the cleaned and moistened surface of the hardened concrete, including vertical and inclined surfaces, shall first be slushed with a coating of neat cement grout against which the new concrete shall be placed before the grout has attained its initial set. Concrete for the first 6 in. of the next layer shall consist of a mix having one-half the amount of coarse aggregate in the regular mix.

(34) Protecting and Curing—All exposed surfaces of concrete shall be protected from premature drying and freshly placed concrete shall be protected against wash by rain. All concrete shall be kept wet for a period of 5 days after placing, except that 2 days' curing shall be considered sufficient if high early strength portland cement or concrete is used.

(35) Depositing in Cold Weather—Concrete when deposited shall have a temperature not below 70 deg. F. and not above 100 deg. F. In freezing weather suitable means shall be provided for maintaining the concrete at a temperature not lower

than 70 deg. F. for 3 days, or 50 deg. F. for 5 days after placing, except when high early strength portland cement or concrete is used the temperature must be maintained at not less than 70 deg. F. for 2 days or 50 deg. F. for 3 days. The methods of heating the materials and protecting the concrete shall be approved by the Architect. Salt, chemicals, or other foreign materials shall not be mixed with the concrete for the purpose of preventing freezing.

(36) Patching—Any concrete work not formed as shown on the plans, or which for any reason is out of alignment or level or shows a defective surface, shall be considered as not conforming with the intent of these specifications and shall be removed from the job by the Contractor at his expense, unless the Architect grants permission to patch the defective area, which shall be done in accordance with the following procedure. Permission to patch any such area shall not be considered a waiver of the Architect's right to require complete removal of the defective work if the patching does not, in his opinion, satisfactorily restore the quality and appearance of the surface.

Immediately after removing forms, all concrete surfaces shall be inspected and any poor joints, voids, stone pockets or other defective areas permitted by the Architect to be patched and all tie holes shall at once be patched before the concrete is thoroughly dry. Defective areas shall be chipped away to a depth of not less than 1 in. with the edges perpendicular to the surface. The area to be patched and a space of at least 6 in. wide entirely surrounding it shall be wetted to prevent absorption of water from the patching mortar. The patch shall be made of the same material and of the same proportions as used for the concrete except that the coarse aggregate shall be omitted and white cement shall be substituted for a part of the gray cement to match the color of the surrounding concrete. The amount of mixing water used shall be as little as consistent with the requirements of handling and placing. The mortar shall be re-tempered without the addition of water by allowing it to stand for a period of 1 hour during which time it shall be mixed with a trowel to prevent setting.

The mortar shall be thoroughly compacted into place and screeded off so as to leave the patch slightly higher than the surrounding surface. It shall then be left undisturbed for a period of 1 to 2 hours to permit initial shrinkage before being finally finished. The patch shall be finished in such a manner as to match the adjoining surface. On exposed surfaces where unlined forms have been used the final finish shall be obtained by striking off the surface with a straight-edge spanning the patch and held parallel to the direction of the form marks.

Tie holes left by withdrawal of rods or the holes left by removal of ends of ties shall be filled solid with mortar. For holes passing entirely through the wall a plunger type grease gun or other device shall be used to force the mortar through the wall starting at the back face. A piece of burlap or canvas shall be held over the hole on the outside and when the hole is completely filled the excess mortar shall be struck off with the cloth flush with the surface. Holes not passing entirely through the wall shall be filled with a small tool that will permit packing the hole solid with mortar. Any excess mortar at the surface of the wall shall be struck off flush with a cloth.

(37) Cleaning Walls—All concrete surfaces shall be cleaned with a solution of muriatic acid containing not less than 5 per cent nor more than 10 per cent of acid by volume. The solution shall be applied to the surface previously wetted with clear water by scrubbing vigorously with stiff bristle brushes. Immediately after cleaning, all surfaces must be drenched with an abundance of clear water to remove all trace of acid.

In addition to the above treatment all smooth finish surfaces shall be given the following treatment:

Prepare a grout of about the proportions of 1 part cement to 1 part fine sand. Grout shall be of a consistency that will permit its application to vertical surfaces with a stiff bristle brush. The grout shall be brushed on the previously dampened surface to fill completely all air bubbles and indentations in the concrete. Allow grout to remain on wall until the cement has partially set, then remove excess grout with a steel trowel. After drying for an hour or longer, depending on weather conditions, rub the wall vigorously with burlap or completely clean the grout from the surface leaving pits filled, but there shall not be a visible film or grout on the surface.

Deep stains and incrustations of mortar or grout shall be removed by scouring with steel wool or fine steel brushes.

If any part of the above treatment is deemed unnecessary by the Architect because of the satisfactory appearance of the job, proper credit shall be allowed the Owner by the Contractor.

* As a rule, vibration in one place should be continued not less than 15 seconds, and not more than 1 minute.

** In the exterior walls it is desirable to locate horizontal construction joints at well defined lines such as window sills or heads, rustications or water tables. Joints at the tops of windows allow considerable shrinkage to occur in the concrete panel between the windows, thereby minimizing the possibility of shrinkage cracks.



The color of the painted walls of Cincinnati Union Terminal is matched in the beautiful, wear-resistant terrazzo floor made with white portland cement and colored marble aggregates. Alfred Fellheimer and Stewart Wagner, architects, New York; terrazzo by Martina Mosaic and Tile Co., Cincinnati.

TERRAZZO SPECIFICATIONS

(1) **Base Slab**—The surface of the structural base slab shall be struck off reasonably true at a level not less than — in. below the required finish grade.

Note: Insert 2 in. for Method A or 3 in. for Method B.

(2) **Samples**—Samples of the aggregates shall be submitted for approval by the Architect. Samples of the terrazzo shall be made in duplicate for approval by the Architect.

(3) **Aggregates**—The aggregates shall be (insert the kind and color desired) and graded in sizes 1, 2 and 3.

(4) **Color Pigments**—Pigments shall be commercially pure natural or synthetic mineral oxides or other coloring materials manufactured for use in portland cement mixtures and proved satisfactory. Pigments shall be in the manufacturer's original container.

(5) **Mixtures**—The base for terrazzo finish shall be mixed in the proportions of 1 part of portland cement to 4 parts of clean, coarse sand.

The terrazzo mixture shall be in the proportions of 200 lb. of aggregate to 1 sack of cement with not more than 4 gal. of water and the proper amount of pigment to produce the approved color. The cement and pigment shall be mixed dry to a uniform color before adding the other materials. The terrazzo mixture shall be of the driest consistency possible to work into place with a sawing motion of the strike-off board or straight-edge. Changes in consistency shall be obtained by changes in the proportions of aggregate and cement. In no case shall the specified amount of mixing water be exceeded.

(6) **Placing**—**METHOD A—BONDED FINISH**—The surface of the structural base slab shall be cleaned of all plaster and other materials that would interfere with bond and shall be thoroughly wetted. It shall be slushed with a neat cement grout thoroughly broomed into the surface. The underbed shall then be spread uniformly and brought to a level not less than ½ in. nor more than ¾ in. below the finished floor.

METHOD B—BROKEN BOND FINISH—The surface of the structural base slab shall be covered with a uniform layer of fine sand ¼ in. thick, and covered with an approved tarpaper overlapping at least 2 in. at all edges. The underbed shall then be spread uniformly and brought to a level not less than ½ in. nor more than ¾ in. below the finished floor.

While the underbed is in a semi-plastic state, the dividing strips shall be installed to conform to the designs shown on the drawings. The top of the strips shall be at least ¾ in. above the finished level of the floor.

The terrazzo mix shall then be placed in the spaces formed by the dividing strips and rolled into a compact mass by means of heavy rollers, adding aggregate if necessary so that the finished surface shall show a minimum of 70 per cent aggregate. Immediately after rolling, the surface shall be floated and troweled to an even surface disclosing the lines of the strips on a level with the terrazzo filling.

(7) **Curing and Protection**—All freshly placed concrete shall be protected from the elements and from all defacements due to building operations. As soon as the concrete has hardened sufficiently to prevent damage thereby, it shall be covered with at least 1 in. of wet sand or other covering satisfactory to the Architect, and shall be kept continually wet by sprinkling with water for at least 7 days when using standard portland cement and for at least 3 days when using high early strength portland cement. The temperature of the concrete at time of placing shall be above 70 deg. F. and it shall be maintained above 70 deg. F. for at least 3 days or above 50 deg. F. for at least 5 days when using standard portland cement and above 70 deg. F. for at least 2 days or above 50 deg. F. for at least 3 days when using standard high early strength portland cement.

(8) **Surfacing**—When the terrazzo concrete has hardened enough to prevent dislodgment of aggregate particles, it shall be machine rubbed, using No. 24 grit abrasive stones for the initial rubbing and No. 80 grit abrasive stones for the second rubbing. The floor shall be kept wet during the rubbing process. All material ground off shall be removed by squeegeeing and flushing with water.

A grout of portland cement, pigment and water of the same kind and color as the matrix shall be applied to the surface, filling all voids.

In not less than 72 hours after grouting, the grouting coat shall be removed and the surface polished to a satisfactory finish by machines using stones not coarser than No. 80 grit.

(9) **Cleaning**—After removing all loose material, the finish shall be scrubbed with warm water and soft soap and then mopped dry.

CONCRETE INFORMATION

SPECIFICATIONS FOR CONCRETE FLOOR FINISH

(1) **Base Slab**—The surface of the structural base slab shall be finished reasonably true and struck off at a level not less than 1 in. below the required finish grade.

As soon as the condition of the concrete base permits and before it has fully hardened, all dirt, laitance and loose aggregate shall be removed from the surface by means of a wire broom which shall leave the coarse aggregate slightly exposed, or the surface otherwise roughened to improve bond with the topping.

When it is impossible to remove laitance and roughen the slab by brooming, the surface shall be cleaned and prepared for bond by chipping after the base has hardened.

Just prior to placing the finish, the base slab shall be thoroughly cleaned by scrubbing, to the satisfaction of the Engineer.

(2) **Portland Cement**—Portland cement shall be of American manufacture conforming to the "Standard Specifications for Portland Cement" (Serial Designation: C-9-38 or the "Standard Specifications for High Early Strength Portland Cement" (Serial Designation: C-74-38) of the American Society for Testing Materials, and subsequent revisions thereof.

(3) **Aggregates**—Fine aggregate shall consist of clean, hard sand or crushed stone screenings free from dust, clay, loam or vegetable matter and shall be graded from coarse to fine to meet the following requirements:

Passing $\frac{3}{8}$ -in. sieve	100 per cent
Passing No. 4 sieve	95 to 100 per cent
Passing No. 16 sieve	45 to 65 per cent
Passing No. 50 sieve	5 to 15 per cent
Passing No. 100 sieve	0 to 5 per cent

Coarse aggregate shall consist of clean, hard gravel or crushed stone free from dust, clay, loam or vegetable matter, and from coatings which will tend to weaken the bond. It shall contain no soft, flat or elongated fragments and shall be graded to meet the following requirements:

Passing $\frac{1}{2}$ -in. sieve	100 per cent
Passing $\frac{3}{8}$ -in. sieve	95 to 100 per cent
Passing No. 4 sieve	40 to 60 per cent
Passing No. 8 sieve	0 to 5 per cent

All aggregates shall be selected with care. Coarse aggregate shall be of an approved character and samples of proposed material shall be submitted to the Engineer for approval prior to use.

(4) **Mixture**—The mixture shall be 1 part of portland cement, 1 part of fine aggregate and 2 parts of coarse aggregate by volume. This nominal mix may be slightly varied, depending upon the local conditions, and as the Engineer may direct. If the aggregate is very coarse, the gravel or stone may be reduced, but in no case shall the volume of the coarse material be less than $\frac{1}{2}$ times the volume of the fine.

The mixture shall be determined by the Engineer and once established shall not be changed except upon his written order.

Not more than 5 gal. of mixing water, including the moisture in the aggregates, shall be used for each sack of portland cement in the mixture. Mixing of the concrete shall continue for at least $\frac{1}{2}$ minutes after all ingredients are in the mixer.

(5) **Consistency**—The concrete shall be of the driest consistency possible to work with a sawing motion of the strike-off board, or straight-edge. Changes in consistency shall be obtained by adjusting the proportions of fine and coarse aggregate within the limits specified. In no case shall the specified amount of mixing water be exceeded.

(6) **Placing and Compacting**—The base slab shall be thoroughly wetted just prior to the placing of the finish, but there shall be no pools of water left standing on the wetted surface. A thin coat of neat cement grout shall be broomed into the surface of the slab for a short distance ahead of the topping. The wearing course shall be immediately applied before the grout has hardened, and brought to the established grade with a straight-edge. After striking off the wearing course to the established grade, it shall be compacted by rolling or tamping, and then floated with a wood float or power floating machine. The surface shall be tested with a straight-edge to detect high and low spots, which shall be eliminated.

(7) **Finishing by Troweling**—Floating shall be followed by steel troweling after the concrete has hardened sufficiently to



14 years of trucking heavy loads did not injure this concrete floor finish. Crushed trap rock aggregate was used in this wearing course and the surface was finished by troweling. The hard wearing quality of this floor is largely due to the control of the water-cement ratio in mixing and adequate curing. This floor is at the plant of the Continental Can Company, St. Louis, Mo.

prevent excess fine material from working to the surface. The finish shall be brought to a smooth surface free from defects and blemishes. No dry cement nor mixture of dry cement and sand shall be sprinkled directly on the surface of the wearing course to absorb moisture or to stiffen the mix. After the concrete has further hardened, additional troweling may be required. This shall be done as may be directed by the Engineer.

Note: Surfaces to be ground shall be swept with soft brooms after rolling to remove any water and surplus cement paste that may be brought to the surface. The wearing course shall then be floated and once lightly troweled, but no attempt shall be made to remove all trowel marks.

(8) **Finishing by Grinding**—After the wearing course has hardened sufficiently to prevent dislodgment of aggregate particles, it shall be ground down with an approved type of grinding machine shod with free, rapid-cutting abrasive stones to expose the coarse aggregate. The floor shall be kept wet during the grinding process. All material ground off shall be removed by squeegeeing and flushing with water.

Air holes, pits and other blemishes shall then be filled with a thin grout composed of 1 part of fine sand and 1 part of portland cement. This grout shall be spread over the surface and worked into the pits with a steel straight-edge, after which the grout shall be rubbed into the floor surface with the grinding machine.

After all patch fillers have hardened for 7 days, the floor surface shall receive a second or final grinding to remove the film and to give the finish a polish. It shall then be thoroughly washed and all surplus material removed.

(9) **Curing and Protection**—All freshly placed concrete shall be protected from the elements and from all defacement due to building operations. The Contractor shall provide and use tarpaulins when necessary to cover completely or enclose all freshly finished concrete.

If at any time during the progress of work the temperature is, or in the opinion of the Engineer will, within 24 hours, drop to 40 deg. F., the water and aggregate shall be heated and precautions taken to maintain the temperature of the concrete above 70 deg. F. for at least 3 days or above 50 deg. F. for at least 5 days when using standard portland cement and above 70 deg. F. for at least 2 days or above 50 deg. F. for at least 3 days when using standard high early strength portland cement.

As soon as the cement has hardened to prevent damage thereby, it shall be covered with at least 1 in. of wet sand, or other covering satisfactory to the Engineer, and shall be kept continually wet by sprinkling with water for at least 7 days when using standard portland cement or for at least 3 days when using high early strength portland cement. In lieu of other curing methods, the concrete may be covered with asphalt-impregnated, waterproof paper. All seams of such paper shall be overlapped and sealed with tape.

CONCRETE ASHLAR

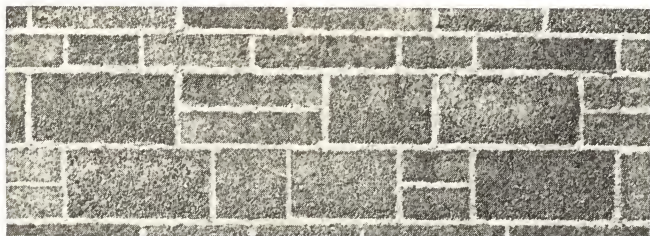
Concrete ashlar in many attractive patterns is a popular treatment for both exterior and interior walls. Note exposed concrete joists in ceiling at right.



Concrete ashlar is an exposed or painted concrete masonry wall employing one or more sized units in its construction. The units may be laid in regular courses, which is known as "coursed" ashlar. Laid in a random pattern, it is known as "random" ashlar. An almost endless number of attractive patterns can be produced by different arrangement of the units in the wall. The surface texture of the units can be varied over a wide range, from a smooth to a coarse, open texture, according to the effect the architect wishes to produce.

Usually the wall surface is given two or more coats of portland cement paint. For exterior exposed work, this paint helps seal the surface, producing a watertight wall. Any color desired can be obtained by adding proper mineral pigments to the paint. With many textures, patterns and colors available, this method of construction has become increasingly popular.

Suggested Concrete Ashlar Patterns—It is recommended that standard sizes of concrete masonry units or multiples of standard sizes be used wherever possible in ashlar work. The fewer sizes



Example of coursed ashlar. One 4-in. course to each pair of 8-in. courses. Formed by units with nominal face sizes of 8x16, 8x12, 8x8, 4x16, 4x12, and 4x8 in.

PRECAST JOIST CONCRETE FLOORS

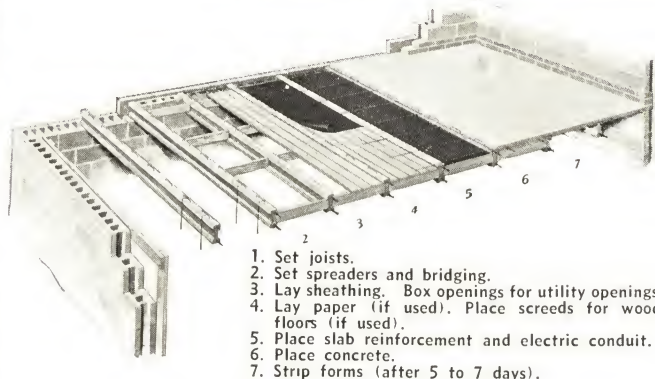
The precast joist concrete floor is a relatively new construction developed to lower the cost of concrete floors—especially suitable for dwellings, apartments and other buildings having relatively light loads. The floor consists of factory-made joists of reinforced concrete which support a concrete slab.

The joists are 8, 10 or 12 in. deep, according to the span and load to be carried, and are usually made in a products plant which delivers them to the site ready for the builder. Usual practice is to place a 2 or 2½-in. concrete slab over these joists. Slab and joists bond together, producing a strong, durable floor.

The underside of the precast joist floor may be left exposed, providing an attractive beamed ceiling effect. If color is desired, portland cement paint may be applied with spray or brush, or the joists may be stained and stenciled. The ceiling may be plastered if desired, plaster being applied on metal reinforcement attached to the underside of the joists.

With concrete as a subfloor any type of floor finish may be used—wood, concrete, tile, carpet, linoleum, rubber tiling, terrazzo or any other popular covering. The concrete itself can be colored and marked off in squares or other pattern, waxed and polished.

7 SIMPLE STEPS IN BUILDING A PRECAST JOIST CONCRETE FLOOR



used, the greater the economy of the wall construction. Most manufacturers of concrete masonry units produce standard sizes and a number of multiples which may be worked into coursed or random ashlar patterns.

Many interesting wall variations may be developed by using only a few sizes of units. Mortar joints also may be handled to produce various effects, depending upon the size of the joints, the manner in which they are struck and the color of the mortar used.



Random ashlar effect achieved by use of only four nominal sizes of units—8x16, 8x8, 4x12, and 4x4 in. Pattern repeats in each square yard of wall area.

CONCRETE INFORMATION

PORTLAND CEMENT ASSOCIATION'S PUBLICATIONS OF INTEREST TO ARCHITECTS

S-4 SWIMMING POOLS

Fundamental principles in locating and constructing outdoor swimming and wading pools are described. Designs for rectangular and oval swimming pools and a circular wading pool are shown. Plumbing layouts and specifications are also included.

S-5 CONCRETE IN SCHOOLS

The designing of school plants to suit curricular programs is given a prominent place in this booklet. Structural layouts and details are illustrated showing architects and engineers how to use concrete to best advantage in design of schools. Contains 22 line drawings and 14 photographs.

S-8 CONCRETE FLOOR FINISHES

Contains information on construction, maintenance and repair of concrete floors. Specifications are included for bonded and terrazzo floor finishes.

S-28 THE NEW BEAUTY IN WALLS OF ARCHITECTURAL CONCRETE

Booklet shows possibilities of concrete as an architectural material for buildings of all types of occupancy and styles of architecture.

T-1 CONCRETE GUIDE

A manual on production of quality concrete for use by contractors and foremen. (Contents largely reproduced on second and third pages of this catalog section.)

T-3 VIBRATION FOR QUALITY CONCRETE

Vibration makes stiff concrete workable and helps to produce dense, watertight, durable concrete. Book covers methods, equipment, test data, recommended practice, bibliography.

T-12 DESIGN AND CONTROL OF CONCRETE MIXTURES

Explains water-cement ratio, field control of concrete and methods of designing mixtures and making tests. A.S.T.M. Standard Specifications for Concrete and Concrete Aggregates are included.

T-18 ANALYSIS OF SMALL REINFORCED CON- CRETE BUILDINGS FOR EARTHQUAKE FORCES

Presents designers with a method of analysis in simplified form for the complete design of small reinforced concrete buildings.

T-20 CONTINUITY IN CONCRETE BUILDING FRAMES

Presents analyses of building frames of reinforced concrete subject to either vertical or horizontal load—wind pressure and earthquake. Quick, easy and convenient procedures suitable for office design practice are illustrated by many numerical problems.

T-21 FORMS FOR ARCHITECTURAL CONCRETE

Contains information pertaining strictly to formwork for architectural concrete buildings. Discusses in detail the design, construction and erection of architectural concrete building

forms, the technique and craftsmanship of which differs considerably from that employed on structural concrete.

T-22 CONCRETE PILES

Discusses pile foundations, pile driving and formulas. The manufacture, handling and driving of precast concrete piles is described and illustrated by photographs. Cast-in-place bearing piles and precast sheet piles are discussed and data for the design of sheet pile bulkheads is given.

T-27 ARCHITECTURAL CONCRETE FOR SMALL BUILDINGS

Contains design and construction information especially applicable to small one and two-story commercial, industrial and public buildings. Plates are included showing form details and layouts.

P-2 CONCRETE ASHLAR WALLS

Features use of variable-sized masonry units to develop architecturally attractive walls for interiors or exteriors. Defines, describes and pictures concrete ashlar construction. Includes suggested patterns for random or coursed ashlar using standard-sized units and multiples thereof.

P-4 PORTLAND CEMENT STUCCO

Illustrates various types of stucco with color plates. Methods of applications and specifications.

P-25 CONCRETE FLOORS FOR RESIDENCES

A manual of residence floor construction describes the solid slab, concrete joist, tile and joist, precast concrete joist, and steel beam concrete floors.

P-26 FACTS ABOUT CONCRETE MASONRY

Manual of reliable, authoritative data, featuring strength tests of concrete masonry walls, specifications and data on construction, fire-resistance, heat-insulation, sound-absorption and transmission, and design data.

P-32 DESIGNED FOR CONCRETE

Fifty-five selected designs from the 1936 *Pencil Points*—Portland Cement Association architectural competition for the design of firesafe concrete homes. Also includes photos of completed houses and information on popular finishes for concrete walls and floors.

P-101 HOW TO DESIGN AND BUILD PRECAST JOIST CONCRETE FLOORS

Manual for use by architects and contractors on the general characteristics, design and construction of floors built with pre-molded joists and job-placed reinforced concrete slabs. Typical specifications and details.

P-143 REINFORCED CONCRETE HOUSES— DESIGN AND CONSTRUCTION DETAILS

Manual explaining the various construction details of the reinforced concrete house.

CONCRETE INFORMATION

PORTLAND CEMENT ASSOCIATION

A National Organization to Improve and Extend the Uses of Concrete

33 West Grand Avenue

Chicago, Illinois

The Portland Cement Association is a research and service organization, supported by companies manufacturing a large proportion of the domestic production of portland cement. Inquiries are invited on any question involving the uses of cement or concrete. Address the general office or nearest district office listed.

ATLANTA, GEORGIA
Hurt Building

AUSTIN, TEXAS
1301 Norwood Building

BIRMINGHAM, ALABAMA
504 Watts Building

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33 West Grand Avenue

COLUMBUS, OHIO
50 West Broad Street

DES MOINES, IOWA
408 Hubbell Building

INDIANAPOLIS, INDIANA
610 Merchants' Bank Building

KANSAS CITY, MISSOURI
Gloyd Building

LANSING, MICHIGAN
Olds Tower Building

LINCOLN, NEBRASKA
321 Terminal Building

LOS ANGELES, CALIFORNIA
816 West Fifth Street

MILWAUKEE, WISCONSIN
735 North Water Street

MINNEAPOLIS, MINNESOTA
814 Northwestern Bank Building

NEW YORK, NEW YORK
347 Madison Avenue

OKLAHOMA CITY, OKLAHOMA
1421 First National Building

PHILADELPHIA, PENNSYLVANIA
1528 Walnut Street

PORTLAND, OREGON
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RICHMOND, VIRGINIA
1210 State Planters Bank & Trust Building

SAN FRANCISCO, CALIFORNIA
564 Market Street

SEATTLE, WASHINGTON
903 Seaboard Building

ST. LOUIS, MISSOURI
1306 Syndicate Trust Building

VANCOUVER, B. C., CANADA
Birks Building

WASHINGTON, D. C.
837 National Press Building